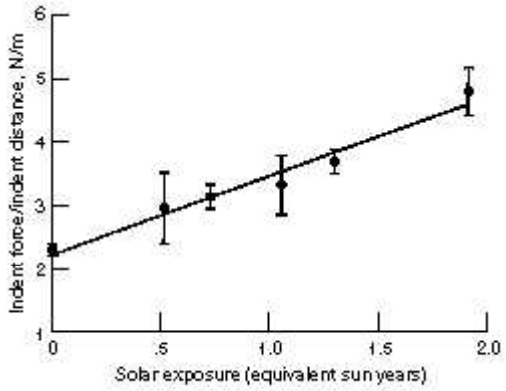
Technique to Predict Ultraviolet Radiation Embrittlement of Polymers in Space

In the low-Earth-orbit environment, solar ultraviolet (UV) radiation embrittles polymer materials through bond breaking and crosslinking. This UV embrittlement increases the surface hardness of the polymer. Before the durability of polymer materials in the low-Earth-orbit environment can be predicted, the extent of UV embrittlement needs to be determined. However, traditional techniques for measuring the microhardness of materials cannot be employed to measure changes in the hardness of UV-embrittled surfaces because traditional techniques measure bulk hardness and are not sensitive enough to surface changes. A unique technique was used at the NASA Lewis Research Center to quantify polymer surface damage that had been induced by UV radiation. The technique uses an atomic force microscope (AFM) to measure surface microhardness.

An atomic force microscope measures the repulsive forces between the atoms in a microscopic cantilevered tip and the atoms on the surface of a sample. Typically, an atomic force microscope produces a topographic image of a surface by monitoring the movement of the tip over features of the surface. The force applied to the cantilevered tip, and the indention of the tip into the surface, can be measured. The relationship between force and distance of indentation, the quantity force/distance (newtons/meter), provides a measure of the surface hardness. Under identical operating conditions, direct comparisons of surface hardness values can be made.

This technique has been used to evaluate small changes in the surface hardness of fluorinated ethylene-propylene (FEP) Teflon (E.I. du Pont de Nemours & Company, Wilmington, Delaware) samples that received varying solar exposures during 3.6 years on the Hubble Space Telescope. The figure shows the increase in surface hardness (represented as indent force/indent distance) with increasing solar UV radiation of Hubble Space Telescope Teflon.



Increase in surface hardness (represented as indent force/indent distance) with increasing solar UV radiation of Hubble Space Telescope Teflon.

Because ground test facilities do not exactly simulate the radiation spectrum of the Sun in space, ground-to-space correlation factors need to be determined for in-space durability predictions that are based on ground testing. The force-versus-distance technique can be used to determine the correlation between ground-testing durability predictions and actual in-space durability. This is achieved by determining what ground-test exposure produces the same UV damage as a particular in-space exposure. The Hubble Space Telescope Teflon data will be compared with ground-test-exposed Teflon data to determine the ground-to-space correlation factor of Teflon. Once the ground-to-space correlation factors for materials in a particular facility are determined, long-term, in-space durability can be more accurately predicted on the basis of ground testing.